Quaternary Deformation along the East Front of the Diablo Range near Tracy, California: Year 2

Award # 99-HQ-GR-0101

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Program Element II
Keywords: neotectonics, geochronology, paleoseismology, tectonic geomorphology

Investigations undertaken

We are investigating Quaternary deformation associated with the San Joaquin fault, and its implications for seismic hazards assessments along the eastern front of the Diablo Range near Tracy, California. Our first-year trenching investigation of the San Joaquin fault (Award # 1434-HQ-97-GR-03011) has successfully demonstrated the presence of active thrust faulting along the western margin of the San Joaquin Valley. In this second year we are obtaining geochronologic data on the deformed terraces in order to complete our evaluation of the San Joaquin fault as a seismic source.

The San Joaquin fault is located at the prominent topographic escarpment that marks the eastern front of the Diablo Range (Herd, 1979; Bartow et al., 1985; Lettis, 1985; Sowers and others, 1992). The fault is associated with the Coast Range-Sierran Block boundary zone defined by Wong and others (1988). Despite its strong geomorphic expression, the San Joaquin fault is not presently designated an Earthquake Fault Zone by the California Division of Mines and Geology (Hart, 1994), and its surface trace has not yet been documented in a field exposure.

We had previously mapped alluvial units at 1:24,000 scale along about 35 kilometers of the range front (Noller et al., 1993; Sowers et al., 1993a, b), and showed scarps of the San Joaquin fault that appeared to offset possible late Pleistocene or younger alluvium at the range front at two locations, one at the mouth of Lone Tree Creek and the other at Ingram Creek. Because of the presence of more than one offset alluvial terrace, the Lone Tree Creek site was selected for our study.

In 1997 we conducted a paleoseismic trenching investigation where the San Joaquin fault appears to offset two alluvial terraces of Lone Tree Creek. Two trenches were excavated across the steepest portion of the scarp, one on each of the two deformed terraces. The trenches were oriented perpendicular to the scarp and approximately parallel to the downstream direction of the terrace (Figure 1). Four test pits were also excavated on the undeformed portions of the terraces, both above and below the scarp, to help document alluvial stratigraphy and soil-profile development.

In addition, a topographic survey was conducted of the site area to document the geometry of the scarp, the geomorphology of the alluvial terraces, and the location of the trenches and test pits relative to the scarp and terraces.

Results

The topographic survey clearly shows the northwest trending scarp and the relative offset of the terraces (Figure 1). The terraces have an original downstream slope of 1 to 2 degrees. The scarp creates vertical offsets of the terrace treads of 5.5 m and 2 meters, with scarp face slopes of 6 degrees and 3 degrees, respectively, on the older (terrace 7) and younger (terrace 5) terraces. The scarp is approximately the same length across both terraces, about 75 meters. A third, much younger terrace (terrace 3) is not measurably offset.

The trenches expose discontinuously bedded gravelly alluvium with beds that are subhorizontal on the undeformed portions of the terrace but dip parallel to the ground surface down the scarp face. The bedding then flattens out at the bottom of the slope to that of the original alluvial terrace. Well-developed soil profiles on each terrace mantle the step in topography. We found no evidence of surface rupture. We interpret the scarp to be a broad warp, or monoclinal fold.

Thus, the San Joaquin fault does not reach the surface at this site. We interpret a blind thrust or reverse fault at depth whose presence is indicated by surface deformation in the form of a monoclinal fold scarp. These findings are consistent with previous models of the eastern front of the Diablo Range (Wong et al, 1988, Sowers et al., 1992, Unruh et al., 1992). Recent earthquakes on hidden or "blind" thrust faults (the 1983 M 6.5 Coalinga earthquake; the 1994 M 6.7 Northridge earthquake) show that lack of surface rupture does not preclude a significant seismic hazard.

Our second year investigation focuses on obtaining accurate ages for the deformed terraces in order to constrain the rate of deformation. Unfortunately, no charcoal or other organic materials suitable for C-14 analysis were found in the trench exposures. Ages of the terraces will be obtained primarily by application of the U-series and C-14 methods to soil carbonate rinds that coat the undersides of the clasts in the terrace gravels. These data are being augmented by field and laboratory analyses of soil profile development.

The U-series analyses are being conducted by the Berkeley Geochronology Center under the direction of Drs. Ken Ludwig and Warren Sharp. These scientists are currently investigating the isotopic behavior of carbonate in soil environment, and have recent experience in dating soil carbonate rinds in the Wind River Basin and in southern Nevada.

As of this reporting, Drs. Sowers, Ludwig, and Sharp toured the field site and inspected samples of carbonate coatings in the field. Three samples of rind material were analyzed to determine their suitability for providing reliable U-series ages. Results show that not only do the samples contain an adequate concentration of uranium (~2.0-2.5 ppm), but, more importantly, the carbonate contains a sufficiently low detrital Th ($^{230}Th/^{232}Th$)~8-10, implying a detrital age correction of <10%.

All samples of carbonate coatings collected from the 1997 trench exposures have been transferred to the Berkeley Geochronology Center. Dr. Sharp has recently begun sawing up slabs of the clasts and inspecting the coatings under the microscope in preparation for sample selection. Analyses are expected to be conducted in December of 1999. A trial batch will be run first to determine what type of rind material (morphology, crystal size, chemistry) is most successfully dated. Then a second batch will be prepared and run. Final results are expected in February of 2000.

We are also completing our documentation of soil-profile development by conducting analyses of the physical and chemical properties of the soils. The analyses are being conducted at the University of California at Davis under the direction of Dr. Randy Southard. Soil samples were delivered in June of 1999 and the analyses completed in October 1999. Data include clay mineralogy, particle size, pH, iron (FeO, FeD), carbonate, and base saturation. Results of the analyses are expected to be delivered in November of 1999. The soil-profile data will enable us to refine the estimated ages and thus will provide another valuable cross-check for the U-series ages.

At this stage in our investigation, the timing and frequency of seismic activity is not well constrained. The presence of a two-to-three-times greater slope and vertical offset on the older terrace compared to the younger terrace suggests at least two seismic events have taken place since the formation of the older terrace. Good constraints on the ages of the two deformed terraces as well as the one undeformed terrace will be key in assembling an event chronology and assessing the activity and relative seismic hazard associated with this fault.

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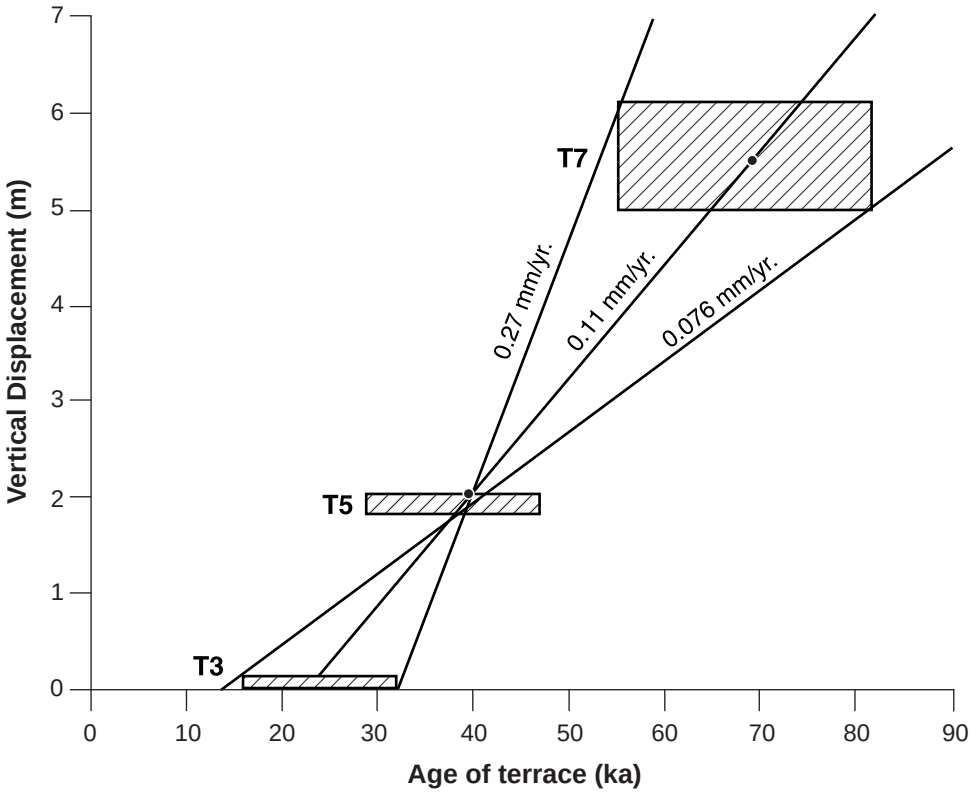

Figure 1. Vertical displacement plotted against terrace age yields rates of vertical displacement ranging from 0.076 to 0.27 mm/yr. The preferred rate is 0.11 mm/yr. Hachured boxes indicate uncertainties.

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Nontechnical summary

The San Joaquin fault coincides with the prominent escarpment at the eastern front of the Diablo Range. Trench exposures across a linear scarp in late Pleistocene fluvial terraces show a monoclinal fold in which alluvial bedding dips 3 to 6 degrees down the 75-m-long scarp face. This suggests the presence of a blind thrust fault at depth. U-series ages of carbonate rinds in the soil, and soil-profile data will provide age estimates for the terrace deposits and allow calculation of rates of deformation. These rates will be used to assess earthquake hazards associated with this fault.

Reports Published

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